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A WET-ROT OF PARA RUBBER ROOTS.

BY

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Assistant Mycologist.

IMPERIAL BUREAU OF MYCOLOGY
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PREFACE.

The work in this country on the Wet-Rot of Hevea roots was completed some time ago, but could not be published in a final form until the systematic position of the fungus causing the disease had been established. This however was not allowed to affect the planter, as articles describing the symptoms, prevention and treatment were published in the *Agricultural Bulletin, F. M. S.*

Owing to the slowness of action of the fungus, the disease is the most insidious and one of the most dangerous of those known to affect Para Rubber. For this reason it is strongly recommended that for all new plantings the clean clearing policy described in the Bulletin be adopted. There seems little doubt that many of the older areas of rubber in this country, where the disease has acquired a strong hold, are doomed to gradual extinction. This should not cause undue alarm, but it must be emphasized that estates possessing such areas will have to meet the problem and should decide on a policy of gradual replanting.

L. Lewton-Brain,

Director of Agriculture, F. M. S.

A WET-ROT OF PARA RUBBER ROOTS CAUSED BY FOMES PSEUDO-FERREUS (WAKEFIELD.)

(Previously described as Poria hypolateritia.)

By W. N. C. Belgrave, B.A.,

Assistant Mycologist.

A preliminary account of the "wet-rot" disease was given in the *Agricultural Bulletin, F. M. S.* (2), where the causal fungus was said to be *Poria hypolateritia,* (Berk.).

Later work showed that in culture, the fungus readily formed pileate fructifications, and a short time afterwards pileate fruit bodies were found naturally occurring; showing that the fungus could not belong to the genus Poria.

The material available was sent to Kew and from it the fungus has been called *Fomes pseudo-ferreus.* As Miss Wakefield points out (8) no perfectly developed fruit bodies are available, and the name must be regarded as liable to revision, if better developed specimens should be found. Owing to the great rarity of the fructifications years may elapse before any perfect specimens are available.

No previous record appears to have been made in Malaya, of a wet-rot of mature Hevea roots. Cases of "wet-feet" were known to planters, but were attributed to water-logging of soil.

The first diseased tree investigated came from wet ground, and the current view of water-logging was accepted. The next series of specimens were from wet, lowlying coastal lands, but diseased trees were soon found in dry situations on undulating land, and finally on the side of a hill with a steep slope at an elevation of 500 feet, disproving the water-logged soil hypothesis.

The dangerous nature of the disease was soon recognised, as the majority of trees killed were over ten years old, and had appeared to be quite healthy.

Field Observations.

The symptoms of an attack by *Fomes pseudo-ferreus* are:—(*a*) Wet rotting of diseased wood, varying from

slight dampness of recently attacked wood to almost complete liquefaction. The rot is most frequently found in roots, as the tree usually blows over before the collar is invaded—cases are on record in which the interior of the collar has been invaded, but not the exterior. So far as is known, nothing resembling wetness is produced by any other fungus in this country.

(*b*) The deep penetration of the disease. The fungus rapidly enters the "heart-wood," and travels fastest there (Fig. 5).

(*c*) Collapse and decay of the inner bark to a thin powdery layer, rendering the removal of the outer bark, when fresh, easy.

The outer bark persists for a long time and frequently becomes matted with late-formed rootlets which die as the fungus advances. Pockets of coagulated latex are often found in diseased bark, but this is fairly common with diseased Hevea, and not a characteristic of *F. pseudo-ferreus*.

(*d*) The frequent but not invariable presence of a tough skin-like dark brownish-red mycelium so intimately bound up with the outer cork layers of bark that superficial examination does not reveal its presence. This mycelium does not cement stones and soil to the root as does that of *Hymenochaete noxia*—(Brown root disease). It is very persistent, and the covering cork layer—mycelium may be all that is left of long attacked roots.

(*e*) The absence of obvious mycelial strands either attached to the root or spreading through the soil. This negative characteristic is of value in distinguishing an attack of *F. pseudo-ferreus* from one of *Fomes lignosus* (*semitostus*).

There are other peculiarities of an attack of "wet-rot" which though typical are not of constant nor even frequent occurrence, so that their absence cannot be used as a proof of the absence of the fungus.

(*f*) The presence, usually on small roots, of a very delicate snow-white mycelium, occurring in patches closely adpressed to the surface (Fig. 7) and easily distinguishable from the cord-like strands of *Fomes lignosus*. It afterwards darkens and merges into the mycelial skin, but is not invariably the first stage of the latter.

(*g*) The presence of small powdery looking yellow pustules about 1/16" in diameter on attacked bark. These appear to be aborted attempts at fructifications.

(*h*) The presence of brown, not black, lines (Figs. 2 and 6) in the wood. The lines are very thin and sharply defined, and as a rule run nearly straight, without the reticulation characteristic of the lines of *Ustulina*. They sometimes curve to enclose small islands, which are more decayed than the surrounding wood. The lines are really the edges of planes of hard brown tissue seen in section.

(*i*) The presence of discoloured light brown areas in the wood. Such areas usually occur near the junction of healthy with diseased tissue, and are often limited on the healthy side by a distinct darker brown band. (Fig. 5).

(*j*) Honeycombing of the wood of Hevea roots (Fig. 3) though rare, is sometimes seen, and is frequently, though not invariably due to *F. pseudo-ferreus*. Such honeycombing is of common occurrence on jungle wood. (Fig. 9).

Spread of the Fungus.

The spread of *Fomes pseudo-ferreus* on plantations is by contact of roots with diseased material—this was clearly shown by one of the earliest cases investigated. One Hevea tree had died, and on opening up was found to be completely "wet-rotted." In the angle made by two of the large laterals was an old much decayed jungle stump, also wet-rotted. (The same fungus was obtained in culture from both rubber and jungle wood). The lateral roots of the diseased tree were followed outwards, and it was found that the laterals of three neighbouring trees had contracted the disease at points of contact.

Another interesting case was that of two dead and three diseased trees in a row; on opening up, a big lateral root of a diseased "kumpas" (*Koompassia malaccensis*) stump was found travelling along the row, and in every case lateral contact had been established.

Large numbers of similar cases have since been found, abundantly proving the spread of the fungus under plantation conditions to be by contact of roots, either with the diseased roots or stumps of jungle trees, or with other diseased Hevea roots. *F. pseudo-ferreus* has been found to attack all kinds of jungle woods, both hard and soft, white and red, being in fact, especially in early stages, one of the normal fungi causing decay of jungle timber in Malaya, hence no system of selective clearing can be devised to afford protection to Hevea.

All the symptoms of an attack of the fungus so far described, have referred to parts of the plant normally in-

visible, viz. roots and lower part of the collar; opening up is necessary to find the disease while the tree is yet standing. Added to this invisibility, shared with all root diseases, *F. pseudo-ferreus* has a slowness of advance into healthy tissues peculiarly its own, with the result that a tree may be badly diseased for many years without showing it. The persistence of diseased trees is aided by the partiality of the fungus for "heart-wood" which has ceased to function in water conduction, and by the fact the attacks are as a rule confined for a long time to one side of the collar. As a result, the water supply is not sufficiently reduced to cause general wilting. There is one sign, however, by which badly attacked trees may often be discovered, viz., the occurrence of bare tips (usually on the highest branch) looking like slight attacks of "die-back." When such tips are seen, at a season which excludes wintering, and the "die-back" does not spread, *F. pseudo-ferreus* may be suspected, and the tree opened up.

Trees are rarely killed by *F. pseudo-ferreus* before their eight year, and the average time for the discovery of the fungus on plantations is 10-12 years. Trees which have been planted very close to, or on top of, diseased jungle stumps may be killed in 5 years. Naturally death follows sooner when the infection is on the tap-root than when the laterals are attacked.

The only reported case of a plantation badly attacked before the eight year gives strong support to the "contact" theory. It is understood that when the jungle was cleared an abnormal number of diseased jungle trees were found. As the ground was not stumped, there were many centres of infections, instead of the few usually present. Attacks of *F. pseudo-ferreus* are as a rule noticed earlier on wet low-lying than on drier undulating lands, because of the poor root development of Hevea in the former. As soon as two or three laterals become diseased, the tree blows over.

As an instance of the elusiveness of *F. pseudo-ferreus* may be taken the Government Plantation at Kuala Lumpur, where the 17 year old rubber has been found to have about 30% of trees attacked; and this was only accidentally discovered when a tree to tree examination (for other purposes) was in progress.

Investigation of Diseased Tissues.

The material used was either fresh or fixed in alcohol-glycerine (75: 25). Free-hand sections only were cut.

Microscopical examination of sections cut at the junction of healthy with diseased wood, reveals the presence of hyaline branched septate intracellular hyphae, varying from .7 to 1.4 microns diameter. (1 micron = .001 m.m.). The hyphae stain readily with haematoxylin, congo red or cotton blue. Cotton blue, washed out with lacto-phenol, was principally used in this investigation, with aniline safranin as a counter stain when required.

The hyphae are distributed throughout the tissues, and do not advance faster in one group of elements than in another.

In section the brown lines described above are found to consist of thickened fungus tissue, apparently sclerotial in nature (Figs. 8 and 12), thus resembling the black lines caused by *Ustulina zonata*. It is found that in the neighbourhood of a brown line and towards that side of it longest attacked, the normal hyaline hyphae grow larger, denser and thicker walled, increasing from a diameter of .7 to 1.4 microns (Fig. 21) to a diameter of 3 to 6 microns (Fig. 20), with walls 1 to 1.5 microns in thickness. Their staining reactions also change, cotton blue or congo red being no longer effective, while aniline safranin produces a deep stain, *i.e.* the thickening material laid down on the hyphae is not the same as the substance of which they were originally composed. Finally these large hyphae anastomose and thicken till a very dense and dark pseudo-parenchymatous tissue is formed, which takes up none of the ordinary stains (c. f. Petch-6).

The stimulus leading to the production of these lines is obscure, invariably transition hyphae as described are observed on one side, while on the other the line is sharp and well defined, and does not again "shade off" to hyaline hyphae.

It must be emphasised that the lines are really the edges of planes of fungus tissue. Possibly checks to growth due to bad seasons bear some relations to their formation.

Good sections cannot be secured of diseased bark, because of the rapid collapse of the attacked cortical cells. The outer layers consists of a complex of stone cells, walls of dead cells, and fungus hyphae; the last are further aggregated outside to a tough encrusted mass very similar in appearace and reaction to that of the lines just described, but the encrustation process is not carried so far, and the skin is tough, not brittle.

The soft inner tissues frequently disappear leaving behind a powdery layer of cell walls only.

Effect on Tissues of the Host Plant.

The progressive disintegration of the tissues has already been described.

The thickness of the walls of the different elements of a healthy Hevea root are—wood fibres from 3.5 to 4.5 microns—vessels and medullary rays 2.5 to 3 microns. As Petch has stated (6) there is a very thin cellulose lining to the fibres,—this can best be demonstrated in tangential longitudinal section, and Mangin's phosphoric acid-iodine reagent appears to be better than chlor-zinc-iodine. The medullary rays and xylem-parenchyma cells, like the cells lining the vessels are full of starch.

As *Fomes pseudo-ferreus* advances into such healthy tissue, first the starch disappears, then the interior of the cell walls become ragged in appearance, and the violet colouration with iodine-phosphoric acid increases, *i.e.* delignification is in progress. Later, the walls become thinner (Fig. 13) ultimately being reduced to an average thickness of .6 microns and then disintegrate. Progressively the lignin reactions (phloroglucin-hydrocholoric acid, and aniline hydrochloride) become less marked, and towards the end the cellulose reaction also diminishes, until finally only the corners of cell walls react feebly with either set of reagents.

The remainder of the walls however, still stain with slightly acid methylene blue, and bismark brown, the colour being nearly completely washed out with alcohol or glycerine indicating the persistence of the pectic constituents—probably to these the slimy and jelly-like character of much decayed roots is due.

Numerous tyloses—bladder like ingrowths from neighbouring cells—are found in attacked vessels, but are not so characteristic and constant a feature as they are said to be by Brooks and Sharples in Hevea wood attacked by Pink disease (3).

A marked effect of an attack by *F. pseudo-ferreus* on Hevea is the formation of a brown, translucent substance in many medullary ray and xylem-parenchyma cells (Figs. 10 and 11). This substance is not homogeneous, but (Fig. 10) consists of dark droplets in a lighter brown matrix. Neither droplets nor matrices are soluble in water, alcohol, dilute acids, strong boiling hydrochloric or nitric acids, dilute or strong alkalies, ether or benzol. They are slowly disorganised by strong sulphuric acid.

The lighter brown substance in early stages may give a red colouration with phloroglucin and hydrochloric acid, but the reaction is not constant, and is not given by older material. The darker droplets are not stained by this reagent, but are darkened by osmic acid, coloured brown by dilute chromic acid, brown by copper acetate, and blue-black by ferrous sulphate solution exposed to the air—thus showing some affinity to the "wound-gum" of "brown-oak" described by Groom (4). The lighter coloured matrix gives none of these tannin reactions.

This "wound-gum" is often produced ahead of the advancing hyphae forming a discoloured margin between healthy and diseased tissue. No hyphae have been found in the gum. Although formed in living parenchyma cells it is frequently injected into the neighbouring fibres and vessels, where it exercises a decidedly protective action. The cell walls of cells injected with "wound-gum" remain intact when those of the surrounding cells are rapidly disintegrating (Fig. 10).

Sometimes the production of "wound-gum" occurs in the form of a wide plate, showing as a band in section (Fig. 5) at other times it may be laid down in a reticulate manner, and persistence of the injected cells gives rise to honeycombing. This is rather rare in Hevea, but common in the harder kind of jungle timber. Fig. 3 shows the beginning of the process in Hevea and Fig. 9 the end of it in jungle timber.

A more common cause of honeycombing in soft woods is due to the persistence of sclerotial tissue, similar to that forming the brown lines described above.

Fruit Bodies.

Fructifications of *Fomes pseudo-ferreus* are of rare occurrence, their rarity being probably due to the subterranean habit of the fungus—attacked trees blowing over before the disease has reached the exterior of the collar. The diseased tissues exposed are rapidly invaded by quick-growing saprophytes, most often *Trichoderma* sp. and *Hydnum* sp. which prevent further growth of *F. pseudo-ferreus*.

Rarely in the field, and more frequently by keeping recently attacked stumps in a moist atmosphere it is possible to obtain resupinate fructifications (Fig. 19) which are plate-like bodies closely adherent to the substratum, white when young, brown when older, pores minute, regular, round;

substance of the body homogeneous and tough. Basidia and spores are rarely produced. The largest of these fructifications was about 1 foot across, but the average is about 2-3 inches. When they are produced on the under surfaces of roots or stumps sharply inclined to the horizontal, the pores become irregular and elongated. The elongation is greater at the higher end, the tendency being for the pore surface to be brought horizontal again.

The only fructification which yielded a reasonably thick spore deposit was of the resupinate type, and was found growing in the field, on an exposed lateral. The spores were hyaline, round to oval and averaged 3 x 4 microns. They were germinated in water and on wood blocks, and produced cultures exactly similar to those got from the fungus isolated from diseased wood. This fruit body was wrongly attributed (*loc. cit.*) to *Poria hypolateritia* (Berk), but differed from that fungus in the absence of a red crust underneath it.* It agrees more closely with *Poria hypobrunnea* (Petch), although the colour of mature plates is more often white than reddish, but Petch (5) in his description of symptoms makes no reference to the wetness of diseased tissues. This wetness is such a striking feature of wood attacked by *F. pseudo-ferreus* that it renders the identity of the two fungi improbable.

Towards the end of 1916, a fresh set of fructifications was found on the collar of a dead stump lying in a damp situation. They varied from the usual resupinate plates, through white knobs to small spatulate forms about 1½ inches long, with white undersurfaces and yellowish-brown imperfectly zoned upper surfaces. The margins, where growth was in progress were white and slightly swollen. The context was tough and dark brown.

A month later a nest of 3-4 small brackets had formed, of which only one (Fig. 18.) was even moderately well developed. This fruit body, together with culture forms, was sent to Kew and is the type specimen. Neither spores nor basidia were found, and all attempts to obtain cultures failed; but the transition forms observed, and the marked resemblance to some of the pileate fructifications produced in culture make it practically certain that this specimen is a fruit body of the fungus under investigation.

Miss Wakefield (8) describes the fungus and comments, as follows:—

"Fomes pseudo-ferreus, Wakefield.

*I am indebted to Mr. Petch for pointing this out.

Pileus sessilis, dimidiatus, ungulatus vel irregulariter undulato-applanatus, subinde imbricatus, glaber, azonatus, cute rigida sicco rimosa e ferrugineo fusco-umbrina tectus, margine sterili tumido albido. *Contextus* floccosus, e cinnomomeo umbrinus. *Tubuli* concolores, intus albidi. *Pori* minuti, rotundati, crasse tunicati, albidi, tactu flavescentes. *Sporae* non visae.

Federated Malay States. On diseased *Hevea brasiliensis* roots, W. N. C. Belgrave (1917).

The fungus is said to cause a root disease of Hevea. Unfortunately mature sporophores are very rare, and the only one available, from which the above description has been drawn up, is ill-formed and shows no spores. When properly developed fructifications are obtained the description will no doubt have to be revised, but as the species does not appear to agree with any known form, and some means of designation is necessary, it has been thought advisable to name it. The very young sporophores, both in nature, and as obtained in pure culture, strongly suggest a *Ganoderma.* One of the cultures, however, was said to have been obtained from hyaline spores derived from a resupinate fructification, hence the plant cannot belong to this genus. The mature pileus bears a distinct resemblance, as regards colour and texture, to that of *Fomes ferreus,* but it differs from that species in the white pore-mouths and darker flesh."

It may be said that from the practical point of view, spores are not produced under plantation conditions by *F. pseudo-ferreus,* a point of considerable importance to planters when devising preventive measures.

Growth of the Fungus in Pure Culture.

Fomes pseudo-ferreus was first isolated, and may readily be obtained by keeping pieces of attacked wood in a moist atmosphere. The selected pieces should include junctions between healthy and diseased tissue, and should be carefully washed with water, dipped in 1/1000 corrosive sublimate for 2 minutes, and washed again with sterile distilled water.

The fungus mycelium in the neighbourhood of the junction grows out as a snow-white delicate felt (Fig. 4), which may later grow over the entire surface of the block, such aerial mycelium cannot be obtained from parts of the block which have been long attacked, indicating the fungus to have lost vitality.

The mycelium so obtained was transferred to sterilised blocks of Hevea wood in culture tubes, and grew slowly at first but more rapidly afterwards, soon—2-3 weeks—covering the blocks and filling the tube with a snow-white mycelium agreeing in size and appearance with that found in the diseased wood (*v. sup.*). (It was found that the best results were obtained when the culture tubes were supplied with more water than usual, *e.g.* with the blocks half submerged).

Blocks were made with wood taken from both stem and roots, with and without bark. The growth was found to be the same in all, and for convenience, blocks made from the stem without bark have been used throughout the investigation.

The fungus was also tried on potato agar, cellulose agar, and Hevea wood decoction agar with unsatisfactory results. There was slight initial growth only.

The wood block culture tubes kept on the laboratory bench, *i.e.* exposed to strong diffuse light, began after a period of 4-6 weeks to form knob-like outgrowths usually towards the top of the blocks. These slowly developed into fruit bodies, usually of the form shown in Fig. 14, small rounded stalked bodies of a corky consistency and a light brown colour averaging .75 cms. in length and .2 cms. diameter. Round pores of the same approximate size as those found in nature, with raised edges forming hexagonal cells next appeared (Fig. 17). A few basidia are formed, but no spores. The fructifications, like the great majority of those of *F. pseudo-ferreus* are sterile.

Such symmetrical development of the fruit body takes place only when it is formed at the top of the wood block, *i.e.* with the pores vertical. It sometimes happens that a fruit body is produced on the side of the block and then the stalk disappears, and the pores become irregular, still however, with a general tendency to have the long axis of the pores vertical.

If tubes with very young symmetrical fruit bodies, be inclined, the stalk curves round during growth, thus bringing the pores vertical again.

If the fungus be grown on large blocks of sterilised Hevea wood (say 10″ x 6″) in jars, a resupinate type of fruit body is produced on the tops of the blocks.

In wood block tubes kept in the dark an abundance of mycelial growth is produced, but no fruit bodies.

If longer tubes, and wood blocks are used, (say 4-5″) and the tubes are kept in weak diffuse light, much more per-

fectly developed fructifications are formed. The lesser humidity of the tube atmosphere at the point of formation of the fruit bodies in long tubes would appear to be the determining factor.

The fructifications so formed are stalked (Fig. 16), have part of their "under" surface adpressed to the walls of the tube, and the remainder white or light brown, with the regular round pores of *F. pseudo-ferreus* and hexagonal cells, as described above. The "upper" surface is greenish-brown, with irregular zones of darker green. There is a white margin where growth is in progress. The body of the

On most blocks, in addition to the fructifications which develop, many brown lumps are formed (Fig. 14), probably aborted attempts at fruit bodies and akin to the pustules found on diseased roots.

In many old cultures, brown sheets of hard sclerotial-like tissue make their appearance, consisting of enlarged encrusted hyphae forming pseudo-parenchymatous tissue like that described in the wood. The plates are formed when the culture begins to go dry, usually over the lower cotton wool plug, or in the neck of the tube, on the surface of the existing mycelium. The "islands" described in the wood are also sometimes paralleled in old culture tubes—if for some reason, empty "pockets" are formed in the mycelium otherwise filling the tube, when the tube is drying up, these become surrounded by a wall of brown sclerotial-like tissue. The edges of two sheets, may be seen as lines in Fig. 16.

The positions in which the brown tissue is formed suggest changes in the concentration of some substance as the stimulus leading to their formation; this substance might be, among others, carbon dioxide, oxygen, or water.

The progress of the fungus, and the occasional formation of brown lines in the wood of the blocks, is the same as in nature; gradually the wood completely disintegrates to a soppy wet mass. No "wound-gum" has been found in cultures.

Germination of Spores. A spore deposit were obtained from only one (resupinate) fructification by keeping it pores downwards, in a moist atmosphere, over sterilised glass slides.

The spores germinated readily in tap and distilled water, sugar (glucose) solution, decoction of Hevea wood, potato agar, and water containing slips of moist Hevea wood.

The spores become swollen; and 1-3, usually 2 germ tubes are put out. These grow on all the media tried to a length about 10 times that of the spore, (Plate IX, Fig. 22) after which, only on wood did any further growth in length take place.

When either the spores themselves, or pieces of the mycelium thus obtained were transferred to wood blocks, the resultant mycelial growth and fruit bodies were identical with that described above, starting from mycelium from wood.

Inoculation Experiments.

Inoculations were made both on seedlings and trees of Hevea. Wood blocks from cultures about 6 weeks old with a good mycelial growth were selected, split, placed on the root, covered with damp cotton wool and the whole tied up with string.

Seedlings. Average age 6 months—growing in large pots.

I. Seven plants, infected wood applied to an unwounded surface of tap-root. Examined after four months—no infections.

II. Six plants were wounded in the tap-root by cutting down to the wood. The following day the plug of exuded and coagulated latex was removed, and infected wood was applied. After three months the plants all of which appeared healthy, were examined. In only one case had the infection been successful, and there hyphae were found only within .5 cms. of the edge of the wound.

III. Six plants were wounded, the latex removed, as in II and spores placed in the cut: other spores from the same fructification, were simultaneously tested, and their germinating power found to be good. Examined at the end of four months—no infections.

Trees. The trees used were six years old, planted in dry soil on the sides and bottom of a fairly deep, and sharply sloping ravine, through which runs a small stream. They were chosen from different levels so that varying degrees of soil moisture might be included in the experiment.

The trees were lettered 'A' to 'K,' 'A' and 'K' being the highest, 'F' and 'G' the lowest, on opposite sides of the stream.

In every case, the soil was removed as carefully as possible, to expose 2-3 feet of the largest lateral roots, to which the infected wood blocks were applied.

IV. A block was applied to an unwounded surface of one root each of B, D, G, I and K. Examined after eight months—no infections.

V. An area about 3″ x 3″ was scraped lightly—not as deep as the latex bearing layer, on one root each of A, C, E and F; and an infected block applied—after eight months, no infections.

VI. One root each of A to K was cut down to the wood, the outer tissues removed, and an infected block applied. Examined after nine months; results were as follows:—

Infections successful .. A, C, D, F, I, J.

Infections failed .. B, E, G, H, K.

The distribution of successful infections indicates that within wide limits the variation of water content of the soil does not affect the power of *Fomes pseudo-ferreus* to attack living tissue.

Even after nine months, the area of diseased wood was limited, showing the slow growth of the fungus. The usual distribution was a thin strip of discoloured and softened wood, running longitudinally for 2-4 inches.

Microscopic examination showed the tissues to be invaded by one and only one kind of fungus mycelium.

The infected roots were cut out, and kept in a moist atmosphere. In three days the characteristic white mycelium of *F. pseudo-ferreus* made its appearance. Pieces of the mycelium were transferred to wood blocks in culture tubes, on which eventually, fruit bodies, similar to the simple stalked form described above as growing in culture, were produced.

Control. VII. One root each of E, F, G was wounded by cutting to the wood, and bound up with damp cotton wool. Examined after nine months. Callus formation had taken place, but no hyphae could be detected in the tissues surrounding the wound.

The above experiments may be summarised thus:—

		No. of plants inoculated.	Infections.
Seedlings.			
I.	Unwounded.	7	0
II.	Wounded.	6	1 ?
III.	Wounded.	6 (spores)	0
Trees.			
IV.	Unwounded.	5	0
V.	Scraped.	4	0
VI.	Wounded.	11	6

Control (uninfected)
Wounded. 3 0

Except in III, the sources of infection were wood blocks from pure cultures.

Places of infection .. Seedlings .. tap-roots.
Trees .. laterals.

The above experiments prove that *F. pseudo-ferreus* can invade the tissues of roots of mature Hevea, healthy but for surface wounds; and indicate that it cannot penetrate unbroken bark, *i.e.*, like so many partially parasite fungi, it is a "wound parasite."

Treatment.

As a rule attacks are not discovered till so much damage has been done that treatment of individual trees is rarely practicable. It is sometimes possible however, to follow up diseased laterals and cut them near the parent tree at a point to which the fungus has not yet penetrated.

It may be taken as a general rule, that trees attacked by *Fomes pseudo-ferreus* cannot be treated, hence all efforts must be directed towards prevention.

Prevention.

The facts bearing on prevention may be recapitulated thus:—

(*a*) On plantations spore infections may be neglected.
(*b*) Spread is by contact of healthy with diseased roots or stumps either of jungle or rubber trees.
(*c*) The original sources of the fungus on plantations are diseased jungle stumps.
(*d*) The fungus is a "wound parasite."

It might be thought that immunity from attack would be attained by preventing wounds, *e.g.*, by banking soil over the exposed roots Unfortunately a "wound" in this connection, means any break in the protective covering of the plant, and such "wounds" are common without the intervention of animal agency. The death and decay of very small rootlets provides one means of "wounding," strains due to wind may provide another.

Prevention may be of two kinds, (*a*) Exclusion of the fungus from areas intended for Hevea plantations, (*b*) Prevention of spread from infected to healthy areas.

(*a*) To exclude *Fomes pseudo-ferreus* from areas about to be planted up, it is necessary and sufficient to remove all

jungle stumps and roots. When to this is added the necessity of removing surface timber as a preventive of *Ustulina*, a scheme of "clean clearing" is indicated.

Confidence may be felt in the efficacy of such a scheme for preventing "wet-rot," because, for practical purposes, the fungus may be said to produce no spores; and of all the diseased trees examined, not one showed signs of spore infection.

Further evidence is afforded by the comparative immunity of plantations on old lallang (grass) land. Clean clearing was largely carried out on such lands in the process of removing grass roots.

Clean clearing has not been advocated before for prevention of root diseases because it was thought an unnecessary expense. Thus Bancroft (1) says, "there appears to be sufficient evidence to show that the disease (*Fomes lignosus*) can be successfully eradicated if careful attention is paid to the treatment of the infected areas or centres of infections, although the bulk of the timber be allowed to remain. The complete removal of timber from the land would appear in most cases to be extravagant."

The possibility of successful treatment depends on the comparatively rapid invasion of the roots of young trees by *Fomes lignosus*, resulting in early death, and enabling the diseased area to be discovered and treated.

F. pseudo-ferreus does not show itself in this way, it might be eight or more years before a single case is noted on a plantation, and all the time the disease may be spreading. There is thus, no way of differentiating jungle stumps and roots infected with the disease from healthy ones, and all should be removed.

The cardinal objection to clean clearing is the expense entailed. An estimate by two members of the planting community gives for complete clean clearing to a depth of 18", costs ranging from $170 to $260 per acre. Such costs are beyond the resources of most plantations at the time of planting.

By far the greater part of the expense is incurred in the removal of the largest stumps, which are frequently those of the "Kumpas" tree, which has a wood of extreme hardness. (It is also a host for *Fomes lignosus*.) There are seldom more than four such stumps to the acre.

It is suggested that the stumps be left in the ground, and isolated by trenches, run—say—6 ft: from the stumps, and deep enough to sever all lateral roots (2 ft. 6" will usual-

ly suffice). No rubber must be planted within the trenches, which must be kept open as long as the stumps are in the ground. Although the stumps may develop "wet-rot" as there are no connecting roots to serve as a pathway, the fungus cannot get outside the trench. All the smaller stumps must be removed,—on suitable soil "jacks" are very useful—and laterals both of small and large stumps followed up and removed to a depth of 18", or until they becomes less than 1" to 2" diameter. This is best effected by changkolling (hoeing) over the area after the bulk of the timber has been taken off.

When, if ever, the larger stumps have decayed sufficiently they should be removed, and the ground within the trench very thoroughly dug out to remove pieces of diseased wood, six months after this, the trenches may be allowed to fill up. It must be emphasised that until this time, the trenches must be kept open, otherwise rubber laterals will grow in towards the stumps, and establishing contact, permit of the spread of the disease.

The work detailed above, to be absolutely effective, must be carried out as soon as possible after the burn. The removal of surface timber, which plays little or no part in the spread of *F. pseudo-ferreus,* may be delayed up to the time of first thinning out.

Clean clearing becomes less certain as a preventive of fungus root attacks as the age of the plantation increases, because (*a*) some of the trees will already have contracted the disease, (*b*) complete removal of jungle laterals becomes difficult if not impossible. It is, however, fairly certain as a preventive up to the fourth year, and even on old estates, much good can be done by the adoption of clean clearing combined with the system of trenching of diseased trees advocated below, provided the diseased trees are not too numerous, say 25-30 per cent. In such cases the jungle roots and stumps represent a very small proportion of the total infected wood.

(*b*) As for all similar root diseases, isolation of the infected areas by trenching must be adopted (c. f. Bancroft, I. p. 29).

H 1	H 2	H 3	H 4	H 5
H 6	H 7	D	H 8	H 9
H10	H11	H12	H13	H14

H 1	H 2	H 3	H 4	H 5	H 6
H 7	H 8	D1	D2	H 9	H10
H11	H12	H13	H14	H15	H16

Scheme of trenching for 1 or 2 diseased trees.

H = apparently healthy D = diseased.

All the diseased trees in the area should be opened up and trenched, a trench 2 feet deep and 1 foot wide should suffice. Another trench for the sake of safety, should then be run round the apparently healthy neighbouring trees. This second trench is necessary, because of the difficulty even after opening up of making sure that a tree is free from "wet-rot." Once trenched, a tree can take no further part in spreading the disease, so there is no objection, if the tree is a good latex producer, to leaving it until it ceases to yield, or blows over. The trenches must be kept open, until trees are taken out, when the areas should be dug over as completely as possible to remove all wood, and lime may be applied.

Simultaneously, provided the disease is not too widespread, clean clearing should be undertaken. It must be understood that clean clearing after planting up, includes the removal of thinned out rubber stumps and lateral roots, as these also are potential sources of infection, and while decaying, afford any root fungus a rapid means of spread. In addition the stumps form an ideal place for the development of *Ustulina zonata*.

It may be noted that white ants (*Termes gestroi*) may assist in the spread of "wet-rot"—but proof of this has not yet been obtained. Clean clearing may be trusted to prevent this source of spread.

Examination of Plantations for "Wet-Rot."

When it is proposed to reduce trees to less than 60 to the acre, not less than every third tree should be examined. When the limits are to be higher, say 60 to 90, a system of sampling might be adopted. Possibly the fairest method is to examine trees along parallel diagonal rows of the fields, *e.g.* along the lines D. B., F. C., and G. E. The number examined per acre should be not less than 15, the more the better.

A....B....C
D E
F....G....H

Trees having thin foliage, bare branches, or growing near large jungle stumps might be specially examined. The thoroughness of the examination may be allowed to vary with the history of the plantation. The more thorough was the treatment for *Fomes lignosus* in early days, the less *Fomes pseudo-ferreus* is there likely to be, as many of the stumps infected by the latter were removed along with those attacked by the former. There is no doubt that many early cases of *F. pseudo-ferreus* were attributed to *Fomes lignosus* and Brown Root disease, and as a rule, it is on estates where no trenching was undertaken that "wet-rot" is worst.

Replanting of Diseased Areas.

For old and badly attacked plantations—say more than 30% of trees diseased—the wisest policy would appear to be one of gradual replanting. The field or fields on which it is proposed to operate, should be isolated from the rest by deep, wide trenches—deep drains serve the same purpose—the trees felled, and clean clearing of stumps, roots and surface timber carried out as efficiently as possible. It is obvious that this must be thorough, as every piece of wood may be regarded as diseased. To be on the safe side, the field should be rested for a year and changkolled over at least twice, during which operations, a total of—say—2 tons of lime per acre should be worked in. This is a wise precaution in view of the occurrence of hard sclerotial-like tissue in both *Poria* and *Ustulina* (brown and black lines respectively). Though not proved, it is possible that these tissues may be distributed through the soil by decay of the attacked wood and reproduce the disease later. The use of lime should destroy such tissue. After this, replanting may be undertaken.

It is obvious that such treatment will be expensive, but it is unlikely that anything less drastic will be of the slightest use. An experiment is being undertaken by a well-known company to test the effect of omitting the year's rest before replanting, but at least eight years must elapse before any result is attained, and in the meantime it is wisest to rest as indicated.

It must be understood that nothing in the nature of the sudden death of numberless trees throughout the Peninsula on old plantations is anticipated. The proportion of plantations diseased beyond repair is probably small, and in even the worst cases, it will be ten to fifteen years before the

present old rubber becomes useless from root disease. The policy of gradual replanting is suggested, as it could then be carried out from revenue.

SUMMARY.

1. The mode of infection and effects of *Fomes pseudo-ferreus* (Wakefield) are described.
2. Evidence is brought forward of considerable variation in the forms of fructifications.
3. Inoculation experiments on wounded roots of mature rubber have been successful.
4. Treatment is shown to be of little value.
5. Prevention by clean clearing of jungle stumps is recommended.

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EXPLANATION OF ILLUSTRATIONS.

Plate I.	Fig. 1.	Diseased rubber tree showing 2 large laterals completely rotted.
	„ 2.	Section of diseased root, showing rotted tissue on left, and brown lines.
Plate II.	Fig. 3.	Section of base of tree (photographed upside down) showing brown line (on left) and incipient honeycombing (on right).
Plate II.	Fig. 4.	Section of diseased wood, kept in moist atmosphere showing outgrowth of mycelium at junction of healthy with diseased tissue.
Plate III.	„ 5.	Section of young tree which had blown over—showing wood and heart-wood completely rotted; also band of gum round the diseased area.
Plate IV.	„ 6.	Section of diseased lateral root—showing gum line and collapse of bark.
	„ 7.	Lateral root with external mycelium (rare).
	„ 8.	Longitudinal section of diseased tissue showing pseudo-parenchymatous fungus tissue forming brown lines.
	„ 9.	Piece of honeycombed jungle wood.
Plate V.	„ 10.	Transverse section of diseased wood —showing formation of "wound-gum" x 360.
	„ 11.	Do. x 80.
Plate VI.	„ 12.	Transverse section of diseased wood showing brown line x 80.
	„ 13.	Transverse section of diseased wood showing disintegration of cell walls x 360.
Plate VII.	„ 14.	Culture block showing fruit bodies x 2/3.
	„ 15.	Surface view of resupinate fructification x 20.

„ 16. Part of culture showing fruit body and brown lines x $\frac{1}{2}$.

„ 17. Fruit body shown in Fig. 14 x 3.

„ 18. Type specimen x 2/3.

Plate VIII. „ 19. Resupinate fructification x 2.

Plate IX. „ 20. Longitudinal section of diseased wood showing hyphae thickening to form brown line x 450.

„ 21. Longitudinal section of diseased wood showing normal hyphae x 450.

„ 22. Germination of spores x 450.

Fig. 1.

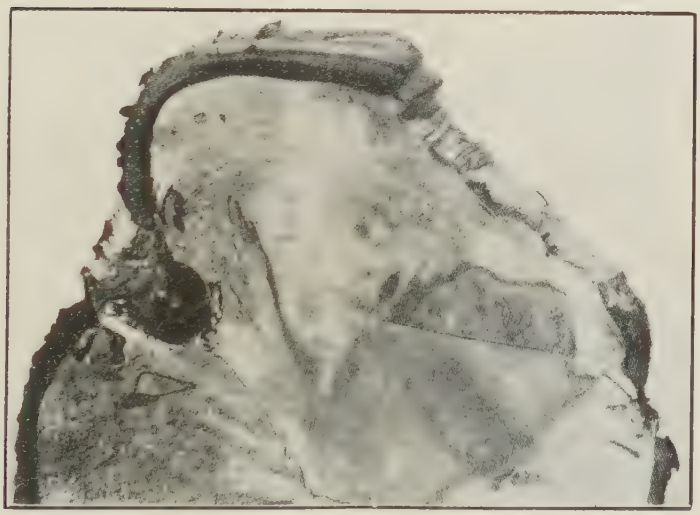

Fig. 2.

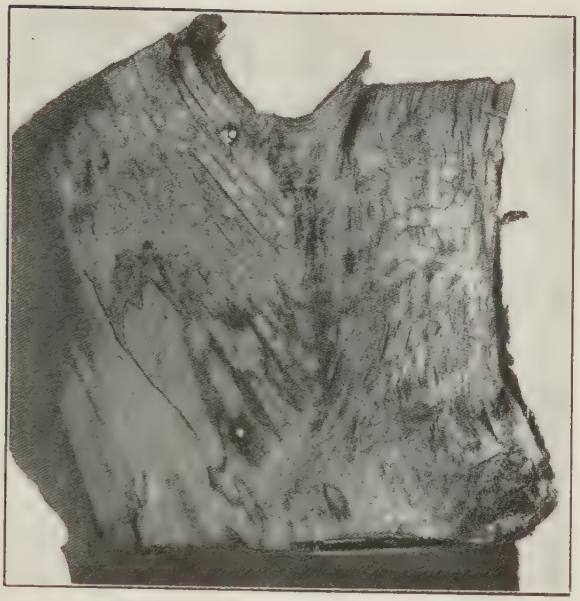

Fig. 3.

Fig. 4.

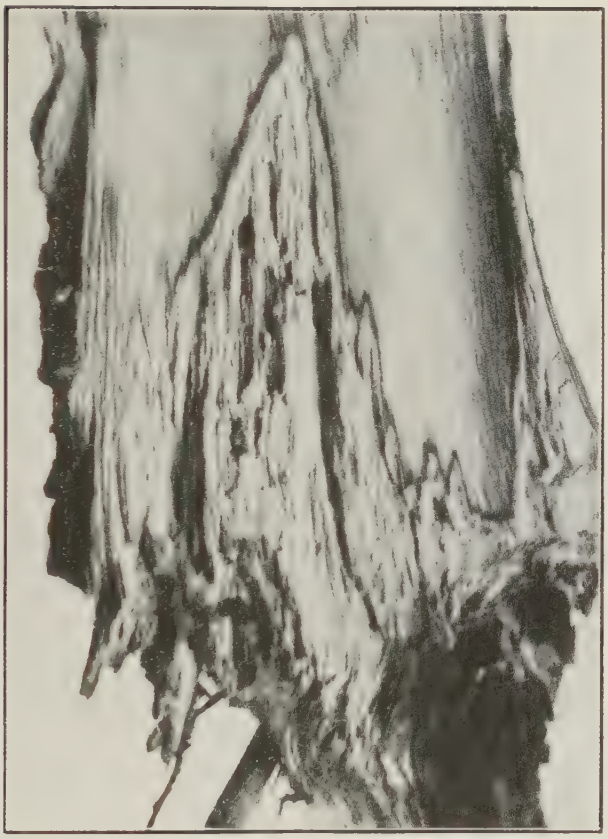

Fig. 5.

Fig. 6.

Fia. 7.

Fig. 8.

Fig. 9.

Fig. 10.

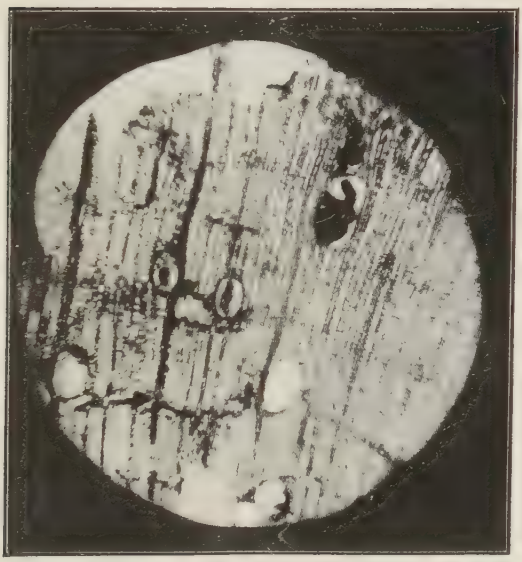

Fig. 11.

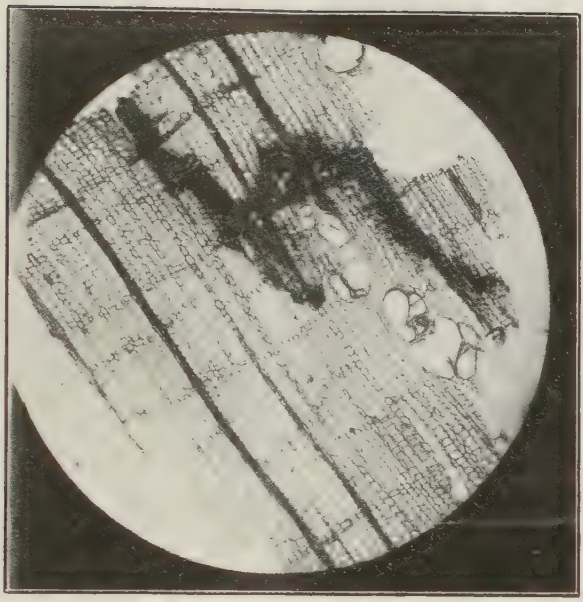

Fig. 12.

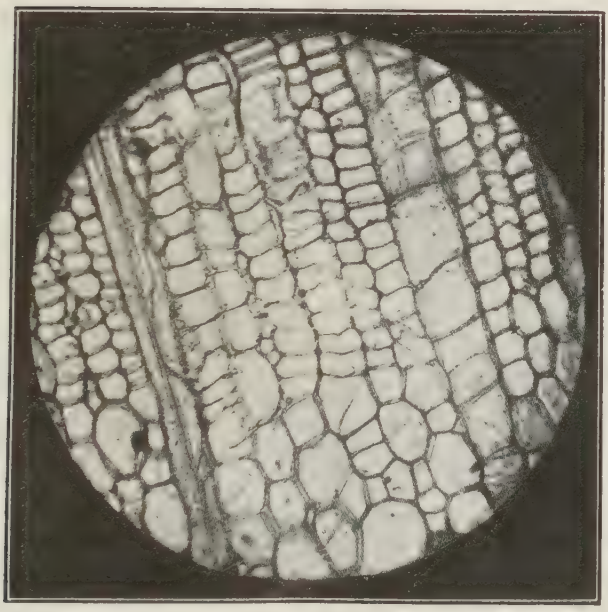

Fig. 13.

Fig. 14.

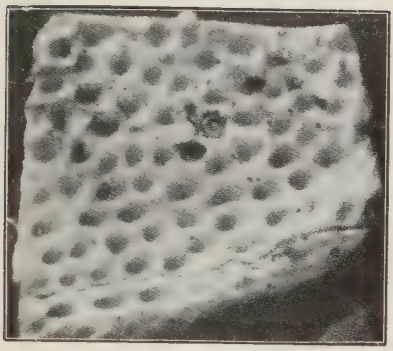

Fig. 15.

Fig. 16.

Fig. 17.

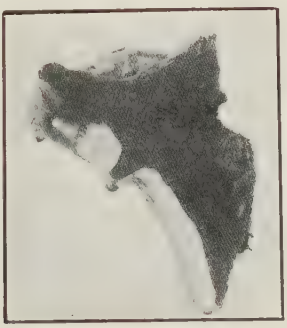

Fig. 18.

Fig 19.

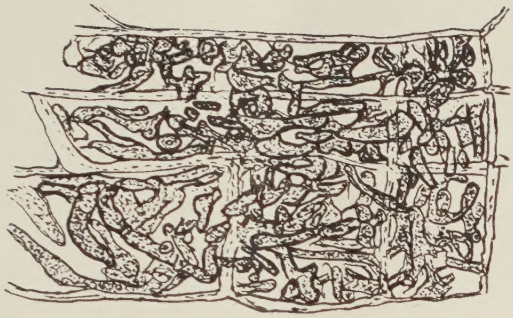

Fig. 20.

Fig. 21.

Fig. 22.

The following Special Bulletins may be obtained on application to the Departmen of Agriculture.

1. Notes on *Termes Gestroi* and other species of Termites found on Rubber Estates in the Federated Malay States, by H. C. Pratt, Government Entomologist. 1909.
2. Root Diseases of *Hevea Brasiliensis*, the Para Rubber Tree, by W. J. Gallagher, Government Mycologist, 1909. Reprint 1916.
3. Observations on *Termes Gestroi* as affecting the Para Rubber Tree and methods to be employed against its Ravages, by H. C. Pratt, Government Entomologist. 1910. Reprint 1916.
4. A Lepidopterous Pest of Coconuts *Brachartona catoxantha. Hamps*, (Zygae nidae) by H. C. Pratt, Government Entomologist. 1909.
5. The extermination of Rats in Rice-Fields, by W. J. Gallagher, Government Mycologist, 1909 Reprint 1916.
6. Preliminary note on a Branch and Stem Disease of *Hevea Brasiliensis*, by W. J. Gallagher, Government Mycologist, 1909. Reprint.
7. Coffee Robusta, by W. J. Gallagher, Government Mycologist. 1910.
8. The Cultivation and Care of the Para Rubber Tree (in Malay) 1910.
9. Die Back Fungus of Para Rubber and of Cacao: by Keith Bancroft, Assistant Mycologist, 1911.
10. A Lecture on the Para Rubber Tree, by W. J. Gallagher. 1910. Reprint 1916.
11. Coconut Cultivation by L. C. Brown, Inspector of Coconut Plantations 1911.
12. Padi Cultivation in Krian, by H. C. Pratt, Government Entomologist. 1911.
13. A Root Disease of Para Rubber, *Fomes Semitostus;* by Keith Bancroft, Assistant Mycologist. 1912.
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16. The Spotting of Plantation Para Rubber (A Preliminary Account of Investigations on the cause of the Spotting), by Keith Bancroft, Mycologist. 1913.
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26. Vegetable Culture in Malaya, F. G. Spring, Agriculturist and J. N. Milsum Superintendent Government Plantations. 1917.
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